AC 2011-1002: OLD TRICKS FOR A NEW DOG: AN INNOVATIVE SOFTWARE TOOL FOR TEACHING REAL-TIME DSP ON A NEW HARDWARE PLATFORM

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Old Tricks for a New Dog: An Innovative Software Tool for Teaching Real-Time DSP on a New Hardware Platform

Abstract

Many university DSP courses have made use of the excellent and affordable tools provided by Texas Instruments, such as the C6000-series of DSP Starter Kits (DSKs). The most recent tool, the LogicPD Zoom$^{\text{TM}}$ OMAP-L138 eXperimenter Kit, featuring Texas Instruments' dual core SoC (ARM9 and a C6748 VLIW DSP), is an even more capable and affordable DSP development system for educators and industry engineers. While this new experimenter kit has several improvements over the TMS320C6713 DSK, the host computer-to-experimenter kit communication techniques have changed dramatically. This paper discusses the continuing evolution of the winDSK software program that was necessary to support this new system. Specifically, winDSK8 was developed to support the C6748 DSP core within the OMAP-L138 SoC using the ARM9 core as the system's communication interface. Educators can use the OMAP-L138 eXperimenter Kit not only for DSP education with a higher performance processor than before, but can use this to introduce the concepts of multi-core devices and system-on-chip designs in a practical way.

1 Introduction

Many university DSP courses have made use of the excellent and affordable tools provided by Texas Instruments, such as the C6000-series of DSP Starter Kits (DSKs). The recent introduction of the Zoom$^{\text{TM}}$ OMAP-L138 eXperimenter Kit from Logic Product Development Company (usually just called LogicPD),[1] featuring Texas Instruments' dual core system on a chip (SoC) that includes an ARM9 and a C6748 VLIW DSP core, has brought a much more capable and affordable DSP development system to both university educators and industry engineers. Note that the name "DSK" and "eXperimenter Kit" are considered synonymous in this context. LogicPD notes that the OMAP-L138 eXperimenter Kit is well suited to a wide range of applications, including those that require high-speed data transfer and high-capacity storage, such as test and measurement, public safety radios, music effects and intelligent occupancy sensors.[1] A photograph of the Zoom$^{\text{TM}}$ OMAP-L138 eXperimenter Kit is shown in Figure 1. Compared to the older, but by no means obsolete, Texas Instruments (TI) TMS320C6713 digital signal processing starter kit (DSK), this new system significantly lowers the cost for educators to implement real-time laboratory exercises and demonstrations in their courses. The current suggested retail price of this new OMAP-based system is $149 (USD),[2] while the suggested retail price for the still-available C6713 DSK is $395 (USD). When compared to the TMS320C6713 DSK, this new experimenter kit has several
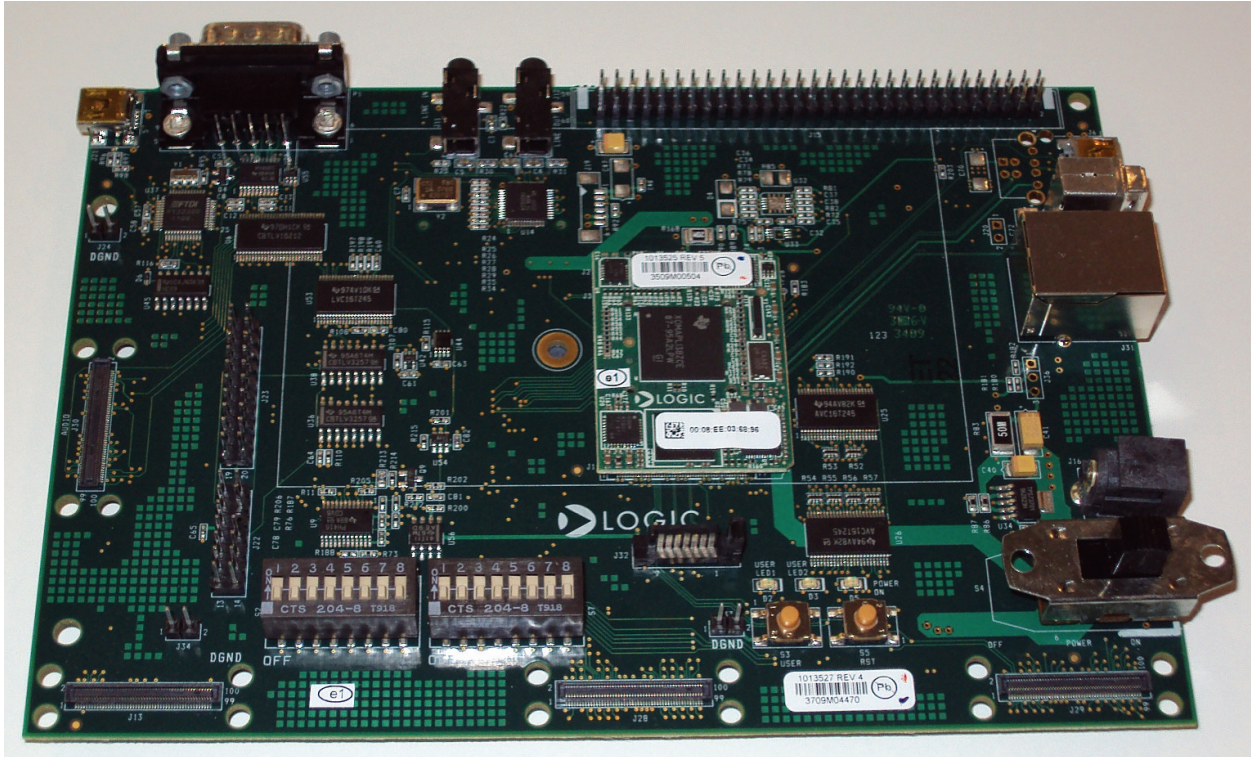
Figure 1: The new LogicPD Zoom OMAP-L138 eXperimenter Kit.

changes, and depending upon the intended application these changes may or may not be considered improvements. The OMAP-L138 SoC includes a multi-core processor that contains both a C6748 VLIW digital signal processor and an ARM926EJ-S RISC general purpose processor, both running at 300 MHz. In the experimenter kit configuration, the processor has 64 MB of DDR RAM and a wide variety of I/O capabilities. The C6713 DSK uses a single-core TMS320C6713 VLIW digital signal processor running at 225 MHz, with 16 MB of RAM. Since both DSPs are from the TI C67x series, most of the code directly associated with signal processing algorithms can be the same, which is a great advantage to professors who have already developed projects and examples using the C6713 DSK. However, the shift to an OMAP SoC has drastically changed the required host computer-to-experimenter kit communication technique needed for most projects and demonstrations.

Specifically, most professors using the older TI TMS320C6713 DSK added a host port interface (HPI) daughterboard that was developed and made available for educators to allow for data transfer, both to and from the host computer, without using the JTAG (IEEE Std 1149.1) debugger interface.[3,4] This was deemed necessary since the JTAG debugger interface is extremely limited in bandwidth, its use required that the TI Code Composer Studio (CCS) software tools are also available on the host computer, and the debugger interface routinely required the DSP to be halted to accomplish data transfer (which tends to negate the whole idea of "real-time" for most applications). Using the HPI daughterboard alleviated these problems, and allowed for the continued use of the existing suite of winDSK6 demonstration software, as well as a number of other custom, but freely available, software tools. These tools were developed for educators as valuable real-time
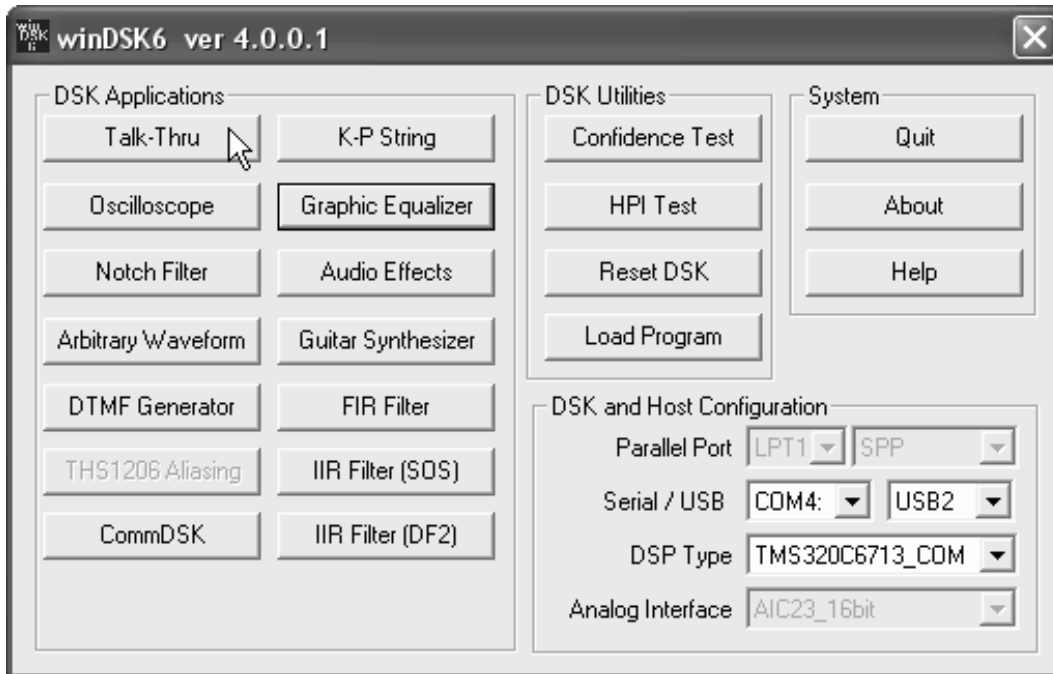
Figure 2: An example of the winDSK6 user interface from 2005.

teaching and classroom demonstration resources.[5–8] Figure 2 shows the winDSK6 opening screen from the 2005 version when this board/software combination was first released. This figure should give the reader some idea of the variety of programs that were initially available.

Many papers have been presented at ASEE over the years that have attempted to answer the question, "How can we best teach real-time DSP concepts to our students?" A quick literature search will confirm that computer-based demonstrations can be very effective with students for many DSP topics.[9–12] The authors certainly agree, and for a number of years we have advocated a systematic use of proven DSP teaching methodologies, coupled with interactive hardware and software solutions, that have helped motivate students and faculty to implement DSP-based systems in real-time.[8, 13–18] This iterative process is depicted in Figure 3. Our approach includes the availability and use of the appropriate version of winDSK. While the suitability of the older C6713 DSK for this approach requires use of the HPI daughterboard for satisfactory performance, the new OMAP-L138 board also suffers from significant "out-of-the-box" interface limitations if it is to be used for DSP lab exercises and demonstrations. Since there is no easy connection to the HPI port available on the OMAP-L138 board, the daughterboard solution we had used for the C6713 DSK was not practical for this new situation.
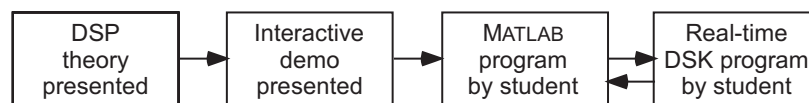

Figure 3: A method of teaching DSP with demonstrations and iterative "hands-on" exercises that expose students to the practical issues inherent in real-time processing.

This paper describes the continuing evolution of the winDSK software program that was necessary to support this new OMAP-L138 eXperimenter Kit. Specifically, winDSK8 is the latest version of winDSK that was developed to access the C6748 DSP core within the OMAP-L138 SoC using the ARM9 core as the communication interface. This not only allows professors and students easy access to higher performance DSP computing power, but also provides an excellent opportunity to introduce the concept of multi-core devices and system-on-chip designs in a practical way. This combination of winDSK8 and the OMAP-L138 eXperimenter Kit is just now available, so no detailed assessment of its use in the classroom yet exists. However, this paper is intended to alert educators to the pedagogical possibilities inherent in these new tools.

2 OMAP-L138 Communications

The LogicPD Zoom OMAP-L138 eXperimenter Kit board has a wide variety of input and output connections (as shown in Figure 4), but the suitability of these connections for DSP laboratory exercises, demonstrations, and other educational methods leaves much to be desired as the board comes out of the box. In addition to a number of specialized connections, the LogicPD Zoom OMAP-L138 eXperimenter Kit has multiple mini-USB connectors, an RJ-45 (Ethernet) socket, and an RS-232 (serial port) connector. One of the mini-USB's is connected on-board to a dual UART and it is intended primarily for debugging purposes; another is intended for emulation. The remaining mini-USB is connected directly to the OMAP-L138, but to use this port to communicate to/from the SoC would require an installed driver stack. We believe the original intent of the OMAP-L138 eXperimenter Kit designers was that this communication task would be accomplished by loading all, or some portion of, a LINUX system that would run on the ARM9 core. While we hope to eventually use either the RJ-45 (Ethernet) or the host port USB connector for host computer communications in a future implementation of winDSK, in this instance the RS-232 port represented a much more readily available, albeit temporary, solution to establishing reliable high-speed host to real-time target communications that would allow the full suite of winDSK programs to run on the OMAP-L138 eXperimenter Kit.

For proper operation, winDSK8 code is loaded into the LogicPD Zoom OMAP-L138 eXperimenter Kit's flash memory utilizing the RS-232 port and a free flash programming utility. This needs to be done only once by the professor or student, unless the user needs to reprogram the flash memory for some other purpose later. Power-on program execution is determined by the board's DIP switches. With the DIP switches in the correct position, upon power up, the ARM9 processor will load winDSK8 code from the flash memory, and the ARM9 then takes control of the C6748 DSP core with communication to the host computer accomplished via the RS-232 port. In this way, the ARM9 is acting in much the same way as the host port interface (HPI) daughterboard acts on the older C6713 DSK, but accomplishes these communication functions locally via the RS-232 port and the SoC without the need for an additional daughtercard. If the host computer to be used has no serial port (as is the case with many laptop computers), an inexpensive USB-to-serial adapter works quite well. We have achieved transfer rates of over 900 kBaud using these adapters (but beware that some older USB-to-serial adapters do not support such high rates). From various personal communications between the authors, Texas Instruments, and LogicPD, we believe that a forthcoming modification to the experimenter kit will allow a more direct connection
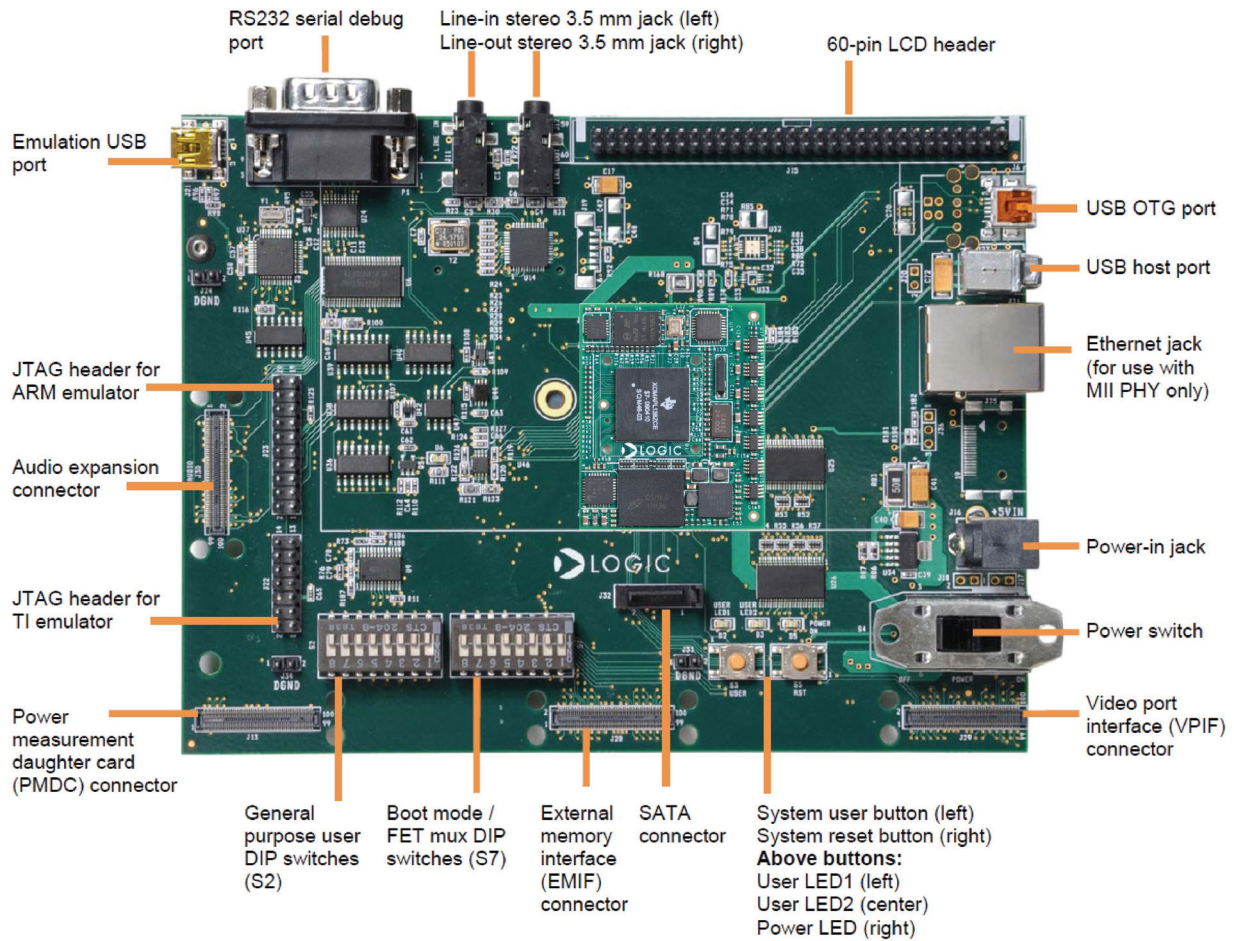
Figure 4: The LogicPD Zoom OMAP-L138 eXperimenter Kit board with various interface ports and communication options labeled.[1]

to the OMAP-L138 UART, bypassing the RS-232 line drivers. However, at the time of this writing the described method is still the best approach.

When using winDSK6 with the older C6713 DSK, the act of clicking on a button in the graphical user interface (GUI) that was running on the host computer initiated a download of the appropriate code from the host to the DSK, and immediately started the code running on the DSK. When using winDSK8 with the new OMAP-L138 experimenter kit, clicking on a button in the GUI running on the host computer sends a short message to the ARM9 on the OMAP board to load the appropriate code from the on-board flash memory into the C6748 and start it running. From the user's perspective, the difference in operation is essentially invisible. The underlying difference between running winDSK6 on the C6713 DSK and running winDSK8 on the OMAP-L138 is that the former uses a USB connection to the HPI daughtercard, while the latter uses a serial RS-232 connection to the main OMAP-L138 board, but the "user experience" is effectively the same. Since we needed to rewrite major portions of the winDSK6 communications interface, we also took this opportunity to enhance many other aspects of the winDSK8 program compared to the previous version.
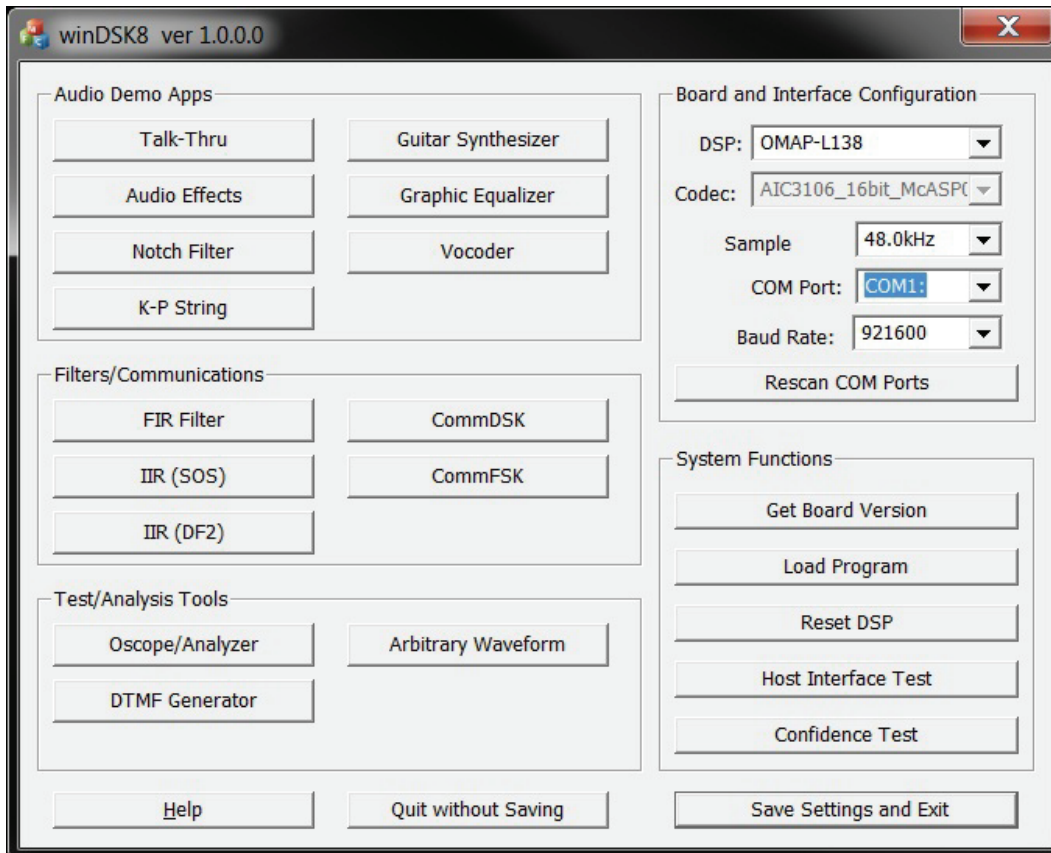
Figure 5: An example of the new **winDSK8** graphical user interface.

3 winDSK8

An example of the new **winDSK8** graphical user interface is shown in Figure 5. While a number of individual winDSK functions have been enhanced, most of the "new look" likely to be noticed by a user is associated with the regrouping of similar functions into sections labeled "Audio Demo Apps," "Filters/Communications," and "Test/Analysis Tools." New programs include the "Vocoder" and "commFSK." Both the regrouping of programs and the inclusion of the two new programs actually took place in one of the final versions of **winDSK6**, before we began to accommodate the OMAP-L138 eXperimenter Kit. Additionally, in **winDSK8**, the "Board and Interface Configuration" section was updated and expanded to support the OMAP-L138 (in addition to all the previously available DSK configurations), allow for a master setting of the system's sample frequency, and for control of the communication parameters associated with the board's RS-232 (serial) port. Based upon our measurements to date, the data transfer rates using the RS-232 port on the OMAP-L138 eXperimenter Kit exceeds the data transfer rates associated with the C6713/HPI-based system. We restate here that since many new computers no longer include an RS-232 port, a USB-to-RS-232 converter cable/system may be needed.

4 Conclusions

The recent introduction of the LogicPD Zoom OMAP-L138 eXperimenter Kit, featuring Texas Instruments' dual core SoC (ARM9 and a C6748 VLIW DSP) has brought a much more capable and affordable DSP development system to both university educators and industry engineers. The OMAP-L138 eXperimenter Kit also makes it relatively easy to to introduce the concepts of multi-core devices and system-on-chip designs to students. As the available real-time DSP hardware has evolved, the winDSK family of programs has also evolved from supporting the C31, the C6211, the C6711, the C6713, and now the OMAP-L138. Each of these migrations has required a unique communication system/interface to allow for high-speed host control of the real-time target. We note that winDSK8 marks the first use of a multi-core real-time target for this type of educational tool, and uses two cores in its operation. The combination of winDSK8 and the OMAP-L138 eXperimenter Kit has just now become available, so no detailed assessment of classroom use yet exists. However, the authors hope this paper will alert educators to the pedagogical potential that could be realized with these new tools.

The winDSK8 program and all of the other software packages that we have developed are freely available for educational, non-profit use, and we invite user suggestions for improvement (see reference 4). Interested parties are also invited to contact the authors via e-mail.

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